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# Solar Optical Materials Laboratory Facilities

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*CSP Peer Review*

*November 8, 2001*

*Albuquerque, NM*

# Outline

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- Background
- Optical Materials Laboratories
- Important Accomplishments
- Problematic Issues
- Summary

# Background

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- Objectives
  - Provide analytical and measurement support for industry needs
  - Provide critical support of Optical Materials R&D efforts
- Importance
  - Supports all three CSP technologies (program's most cross-cutting activity)
  - Unique infrastructure for solar optical materials testing
  - Allows speedy and efficient response to industry needs and requests

# Optical Materials Laboratories

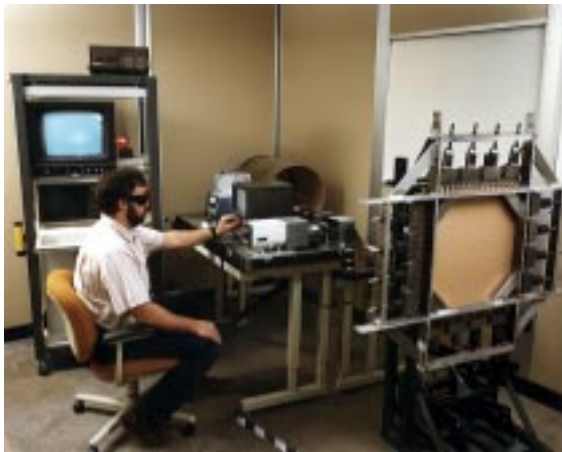
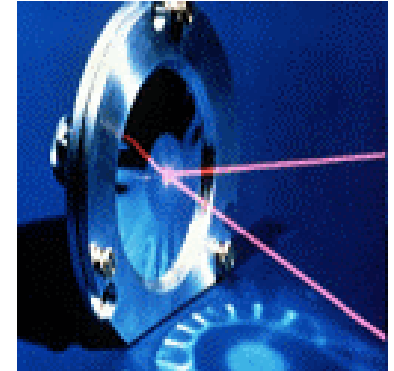
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- Optical Measurements
- Durability Testing
- Analytical Characterization
- Sample Preparation

# Optical Measurements

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- Spectral hemispherical reflectance
- Specular reflectance at specific wavelengths
- Broad spectrum of measurement capabilities



**LANSIR**

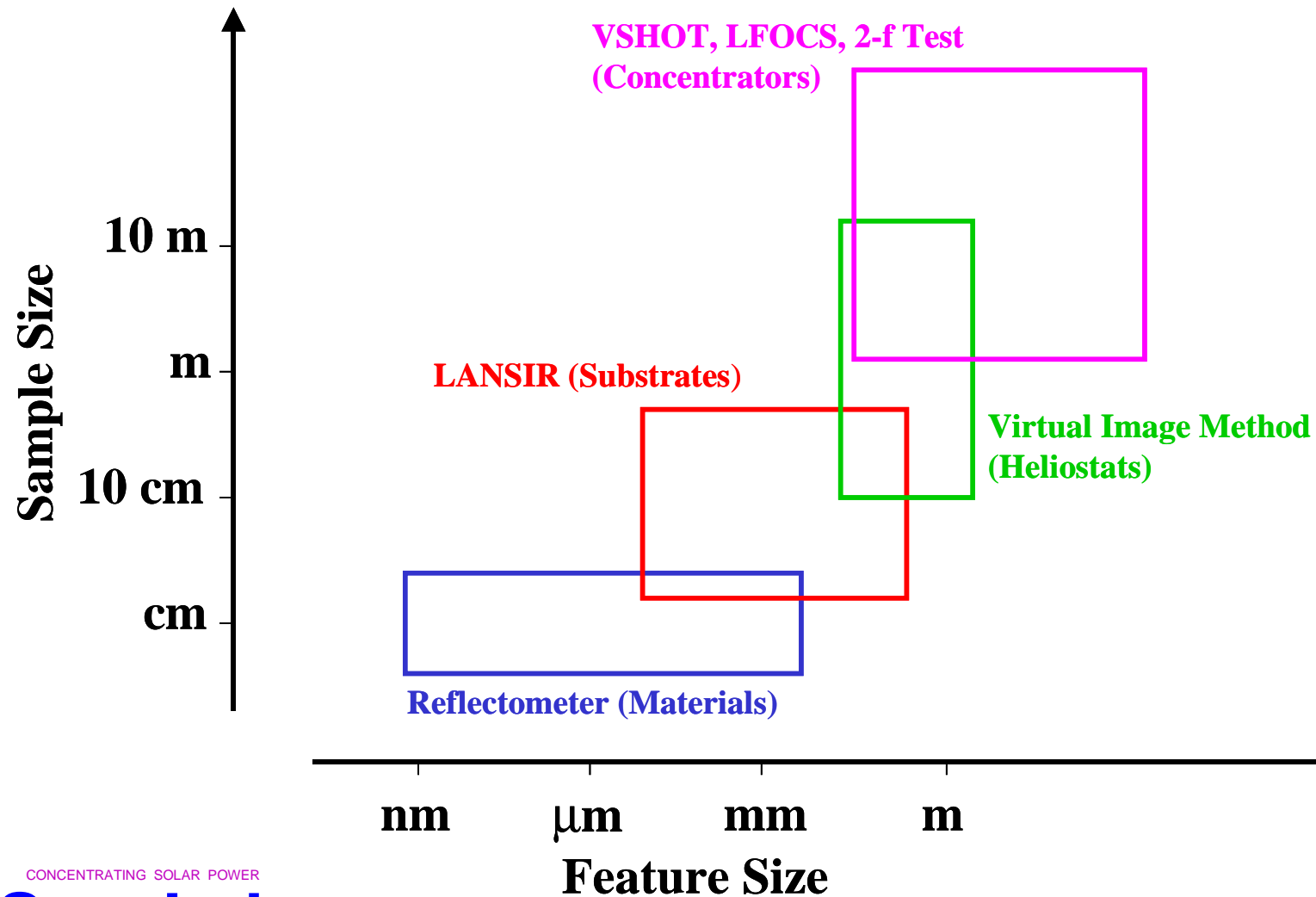


**Specular  
Reflectometer**



**UV-VIS-NIR  
Spectrophotometer**

# Concentrating Solar Power Optical Characterization Tools



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# Durability Testing

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**Outdoor**



**Accelerated  
Laboratory  
Chambers**



**Ultra-Accelerated,  
Natural Sunlight**



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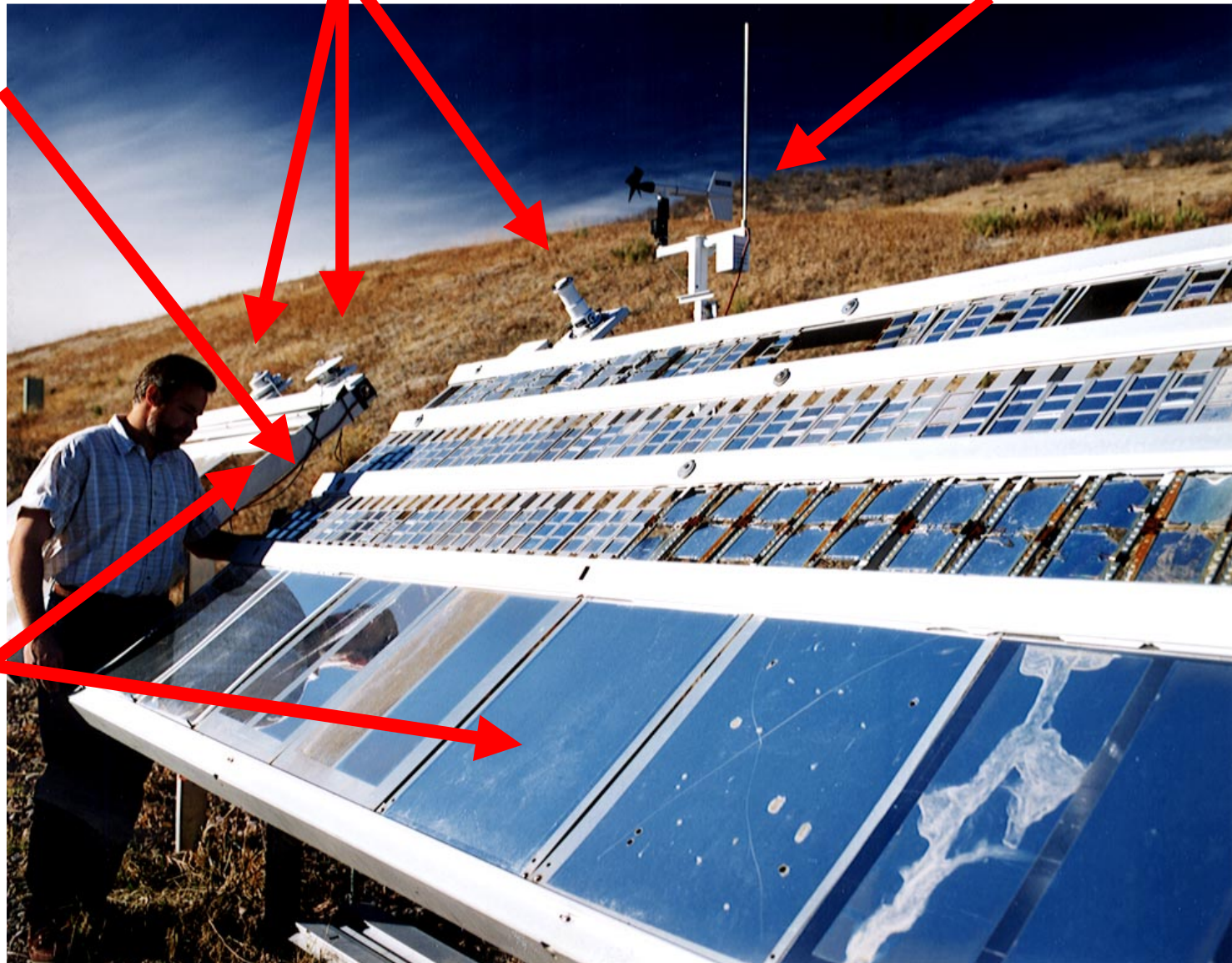
# Typical Outdoor Exposure Test Site

3 Radiometers

Additional meteorological monitoring  
sensors (wind, temperature, relative  
humidity, precipitation, etc.)

Data  
logger and  
modem  
(between  
racks  
unseen)

Racks  
with  
samples  
tilted at  
azimuth  
angle





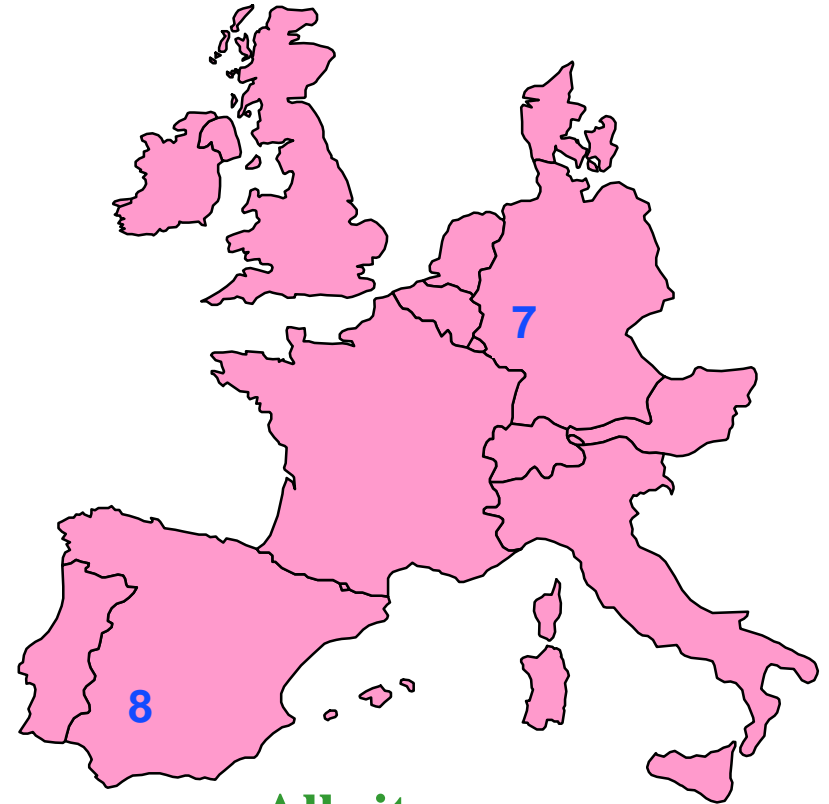
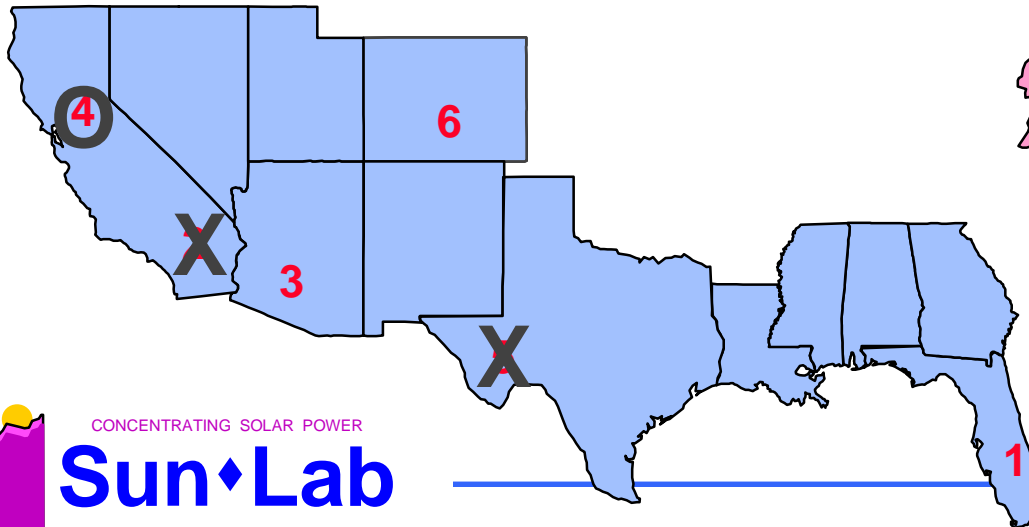
# Outdoor Exposure Test Network

## Site

1. Miami, FL
2. Daggett, CA
3. Phoenix, AZ
4. Sacramento, CA
5. Fort Davis, TX
6. Golden, CO
7. Köln, Germany
8. Almería, Spain

## Stress Conditions

- Hot / Humid  
Hot / Dry  
Hot / Dry  
Warm / Humid  
Warm / Mild  
Cool / Mild  
Warm/Humid  
Hot/Mild



All sites are  
instrumented; 2 new  
sites near Moscow;  
Australia interested



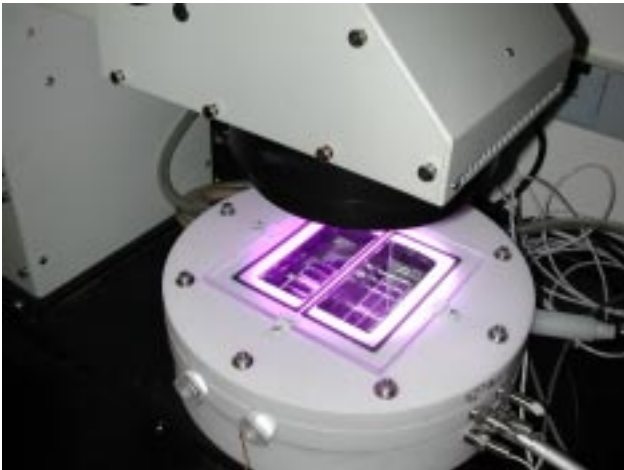
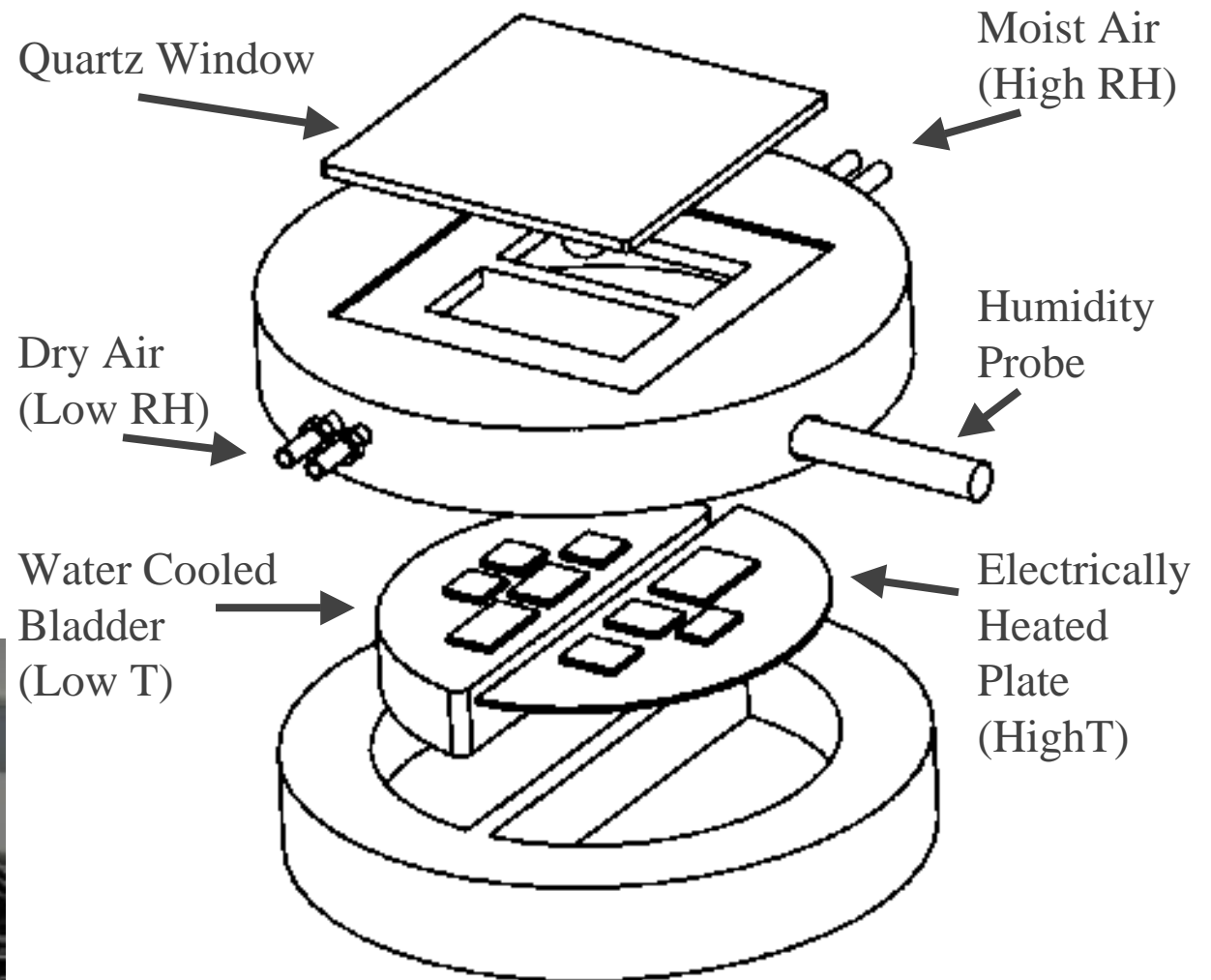
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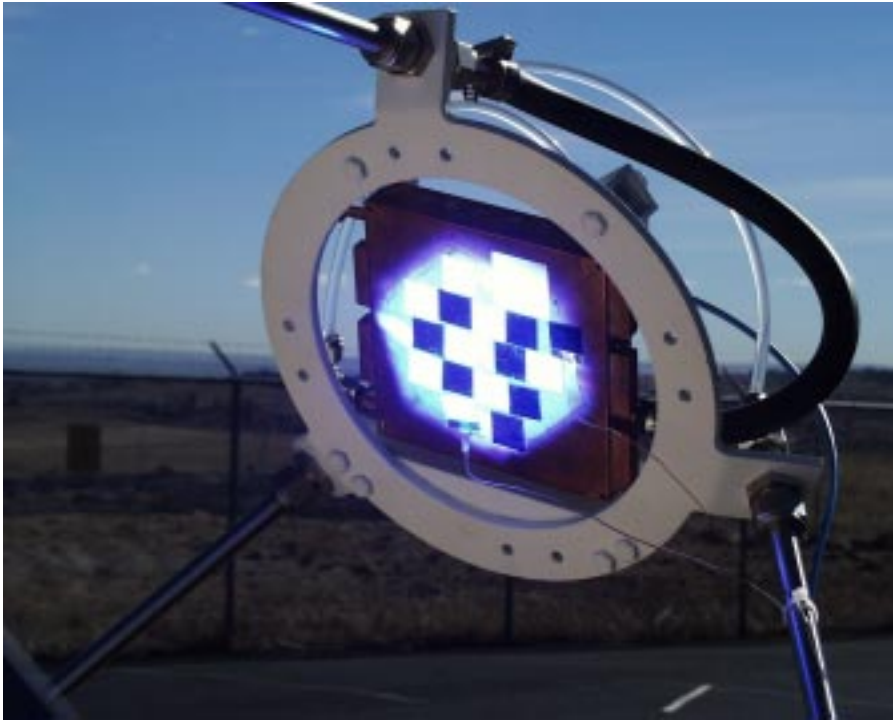
# Solar Simulator Exposure Chamber

- Concurrent testing of 8 samples
- Samples exposed to multiple levels of 3 stress factors
  - UV light
  - Temperature
  - Humidity



# Ultra-Accelerated Test Facility

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**Samples being tested**

- 100 X natural sunlight
- Revolutionary; World-wide unique
- Spectrally split UV
- Major industry partner interested in commercialization

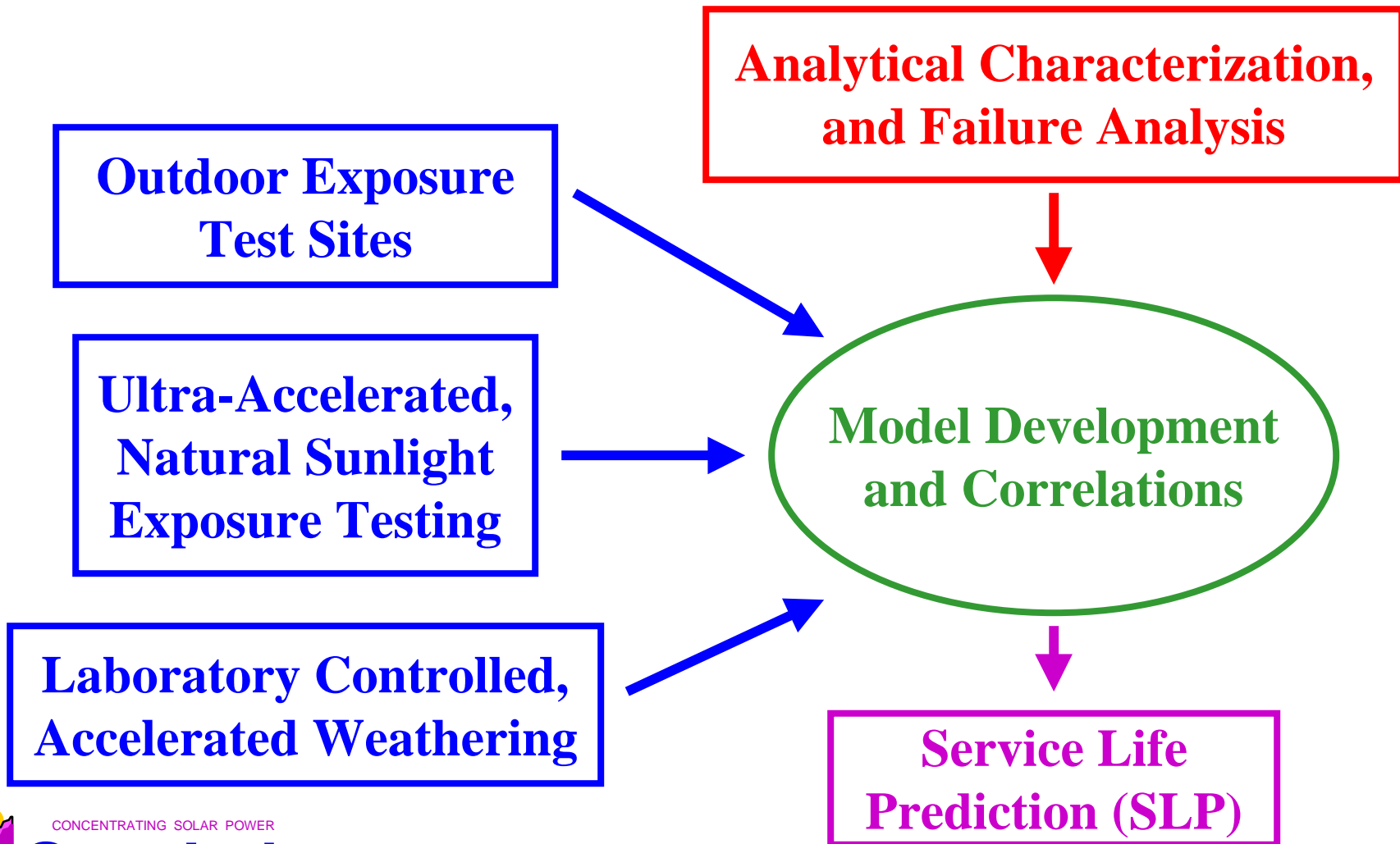


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# Approach to Durability Testing



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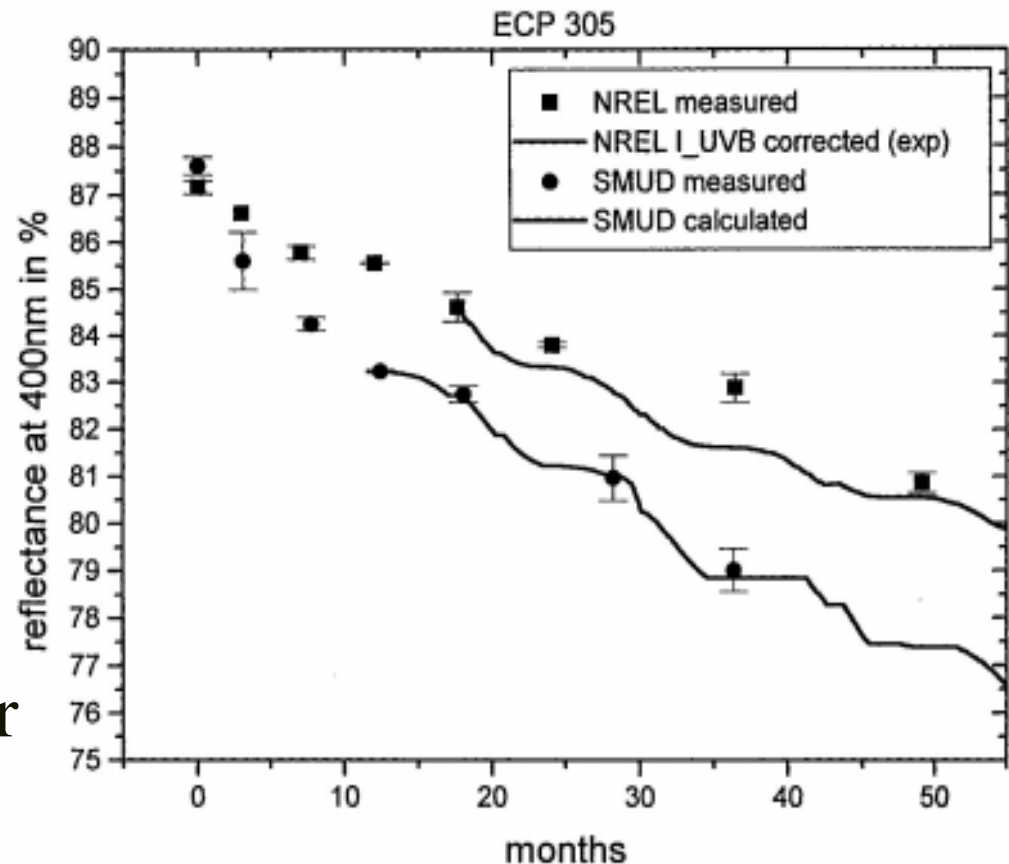
# Comparison of Real-World Measured vs. Predicted Performance Loss

Use constant, accelerated stress exposure to obtain model coefficients:

$$\Delta P = A I e^{-[E/T]} e^{C \cdot RH} \Delta t$$

Use coefficients and outdoor weather data to predict:

$$\Delta P = \sum A I(t) e^{-[E/T(t)]} e^{C \cdot RH(t)} \Delta t$$



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# Analytical Characterization

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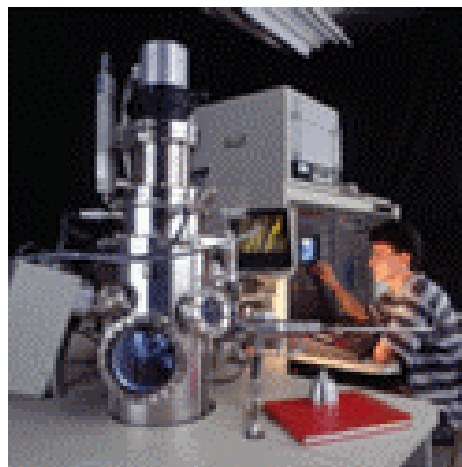
- Help optimize sample preparation
- Failure analysis of exposed samples
- Strong industry support capabilities



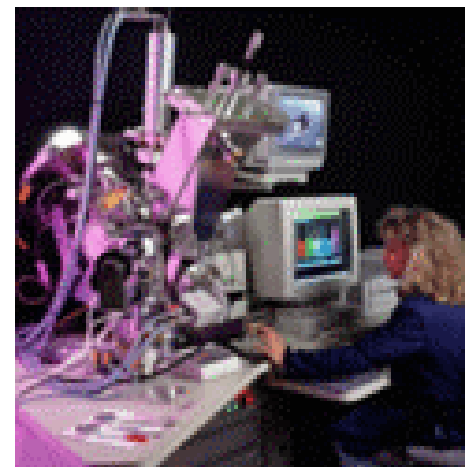
**SEM**



**FTIR**



**Auger**



**XPS**



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# Sun⌚Lab's State-of-the-Art Vacuum Deposition System (Activity Terminated 4/00)

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**Allows timely  
fabrication of  
candidate advanced  
solar mirror  
constructions**

# Important Accomplishments

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- World-recognized Center of Excellence established
- Significant IP transferred to industry
- Substantial support to solar industry provided
- Ability to test candidate solar mirror samples at up to 100 suns demonstrated
- SLP methodology developed and correlations between accelerated exposure testing (AET) and outdoor results validated
- State-of-the-art deposition system activated; process parameters explored; initial constructions fabricated; activity terminated despite successes

# Key Patents

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- Jorgensen, G. J., et al, “Ultra-Accelerated Natural Sunlight Exposure Testing,” U.S. Patent # 6,073,500, June 13, 2000.
- Lewandowski, A. A., et al, “Ultra-Accelerated Natural Sunlight Exposure Testing Facilities,” NREL IR# 00-12, filed March 9, 2000 (continuation in part of 6,073,500).

# Major Publications

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- “Specular Reflectance Properties of Silvered Polymer Materials”, Susemihl, I. and Schissel, P., *Sol. Energy Mater.* 16 (1987) 403-421.
- “LANSIR: An Instrument for Measuring the Light-Scattering Properties of Laminate Membrane Mirrors”, Wendelin, T.J. and Wood, R.L., Proceedings of the Eleventh Annual ASME Solar Energy Conference, San Diego, CA. April 2-5, 1989, pp. 517-523.
- “Durability Studies of Solar Reflector Materials Exposed to Environmental Stresses”, Jorgensen, G.J., Kim, H.M., and Wendelin, T.J., *Durability Testing of Nonmetallic Materials, ASTM STP 1294*, Robert J. Herling, Ed., American Society for Testing and Materials, Philadelphia, 1996.
- “International Collaborative Testing of Solar Reflectors”, Jorgensen, G., Böhmer, M., Fend, T., and Sánchez, M., *Solar Thermal Concentrating Technologies, Proceedings of the 8th International Symposium, October 6-11, 1996, Köln, Germany*, M. Becker and M. Böhmer, Eds., C. F. Müller Verlag, Heidelberg (1997) 443-462.
- “A Unique Facility for Ultra-Accelerated Natural Sunlight Exposure Testing of Materials”, Jorgensen, G., Bingham, C., Netter, J., Goggin, R., and Lewandowski, A., *Service Life Prediction of Organic Coatings, A Systems Approach, ACS Symposium Series 722*, D.R. Bauer and J.W. Martin, Eds., American Chemical Society, (1999) 170-185.
- “Optical Durability Testing of Candidate Solar Mirrors”, Jorgensen, G., Kennedy, C., King, D., and Terwilliger, K., NREL/TP-520-28110, Golden, CO, March 2000.



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# Problematic Issues

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- Mortgage mentality must be dispelled
- Some equipment needs to be modernized/augmented
  - Video reflectometer for specular reflectance measurements
  - Vacuum furnace for testing of candidate absorbers
  - Instrumentation to measure optical properties of candidate absorbers as function of temperature
- Reactivation of deposition facilities for hardcoat development

# Summary

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- Industry cannot afford capital investment associated with this specialized equipment
- Provides additional analytical support to special industry requests on a timely and efficient basis
- Labs serve as central repository for test results and dissemination
- All types of materials tested using same protocols to allow direct comparisons between various candidates
- Ability to track improvements and identify promising new materials
- Standardized tests developed with industry, other national labs, international colleagues, and standards committee